R & D facts

U.S. Department of Energy
National Energy Technology Laboratory

GAS ENERGY SYSTEMS DYNAMICS

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# Gas Energy Systems Dynamics

## Description

The Gas Energy Systems Dynamics focus area within the National Energy Technology Laboratory (NETL) will address the scientific issues needed for breakthrough advances in natural gas utilization technologies. The focus area will integrate this information into the technology development programs managed by the Strategic Center for Natural Gas, and will partner with technology developers to apply these basic science results to commercial products.

The Gas Energy Systems Dynamics focus area will investigate revolutionary advances in gas turbines, fuel cells, hybrid turbine/fuel cells, and reciprocating engines. It is expected these advances will be achieved through research in four major technology areas:

**Evaluating new strategies for combustion and energy conversion.** The focus area will consider several candidate turbine combustion strategies that use fundamentally different approaches for reacting fuel and air. New concepts, such as trapped vortex combustion, catalytic combustion, and surface stabilized combustion may all provide emissions advantages in emerging energy systems. These measurements are needed to advance simulation capabilities for new combustion concepts. The focus area will also investigate new approaches to combustion in natural gas reciprocating engines, and energy generation in fuel cells. The high-pressure facilities at NETL will permit pioneering studies of fuel cell behavior at high-pressure conditions that exist in hybrid energy systems.

**Methods to control reacting flows.** In the past, turbine combustors, fuel cells, and reciprocating engines had simple control systems and were optimized for single operating conditions. Increasingly strict emissions and efficiency constraints coupled with diverse fuel capabilities require new control and optimization strategies. New technologies, such as micro-electronics, wireless controls, embedded MEM valves, laser-based ignition/flame stabilization, and active combustion control and optimization will be investigated.

**Developing new sensors for advanced energy applications.** Achieving the full performance potential of high-efficiency, low-emission energy systems will require sensors capable of monitoring conditions in harsh temperature and pressure environments. Ongoing work at NETL has identified the potential of flame ionization chemistry and aero-acoustic signals as novel methods to monitor the behavior of reacting flows. The focus area will develop these new concepts into sensors that can be used in feedback control strategies to enhance operating flexibility without sacrificing emissions performance. The focus area will also develop research sensors to perform in-situ cell measurements for fuel cell development. These measurements will provide data needed to validate emerging fuel cell models, as well as identify new areas for optimization of cell design.

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NETL

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**Analysis and control of non-linear, coupled systems.** Hybrid energy systems are expected to combine vastly different engine technologies, such as gas turbines and fuel cells. Controlling the coupled system is expected to present significant challenges. The NETL has already developed dynamic models for the fuel cell/gas turbine cycle in order to identify issues with fuel cell transients during hybrid operations.

## Benefits

Improvements to gas energy systems are expected to increase the market penetration of ultraclean power generation in both distributed and central station power generation markets. Reductions in greenhouse gas emissions and other criterion pollutants such as, NOx, will accompany increases in generating efficiency. Substantial deployment of these advanced systems is expected to depend on their operational characteristics (cost, fuel flexibility, adaptability, reliability, and durability). By investigating new methods to improve the operational characteristic, collectively referred to as system dynamics, the focus area will resolve the technical issues that hinder wide deployment of clean-energy generation.

This research will generate public domain data on new energy concepts that will allow both university and private sector research groups to develop new concepts for clean energy generation. For example, collaborations with Sandia National Laboratory will produce data on basic properties of pressurized premixed flames. The hybrid fuel cell/turbine test stand will provide public data on hybrid system integration. These data might otherwise be duplicated (at multiple costs) in individual development efforts. By providing public data on the revolutionary hybrid concept, the focus area will be able to involve multiple university investigators in this emerging technology. The net effect will be to enlarge participation in developing the best ideas for this hybrid energy technology.

The focus area will serve as a technical point of contact for collaboration with NASA and DOD programs in aero-propulsion and marine power generation. This will capitalize on the government investment in high-performance propulsion that is typical of DOD and NASA programs. In reciprocal fashion, low-emission technology developed in the focus area may benefit the environmental performance of DOD and NASA applications. The benefit to all the government agencies is to share technical strengths, and in some cases, share unique government facilities that would otherwise need costly duplication.

## Milestones

- In FY2001, we plan to establish a hybrid fuel cell/gas turbine testing and modeling capability, initiate projects for in-situ monitoring of engine condition, upgrade a reciprocating engine facility for natural gas operation, conduct research in advanced ignition and flame anchoring concepts (laser, plasma, reformat pilot), and initiate a comprehensive preignition (knock) control project for natural gas engines.
- In FY2002, we will begin research with a newly commissioned fuel processing facility, begin to develop novel configurations for knock-resistant reciprocating engines, devel-op and test hypotheses of low-temperature kinetic knock mechanisms, begin Phase I research on a novel, low-emission turbine combust concept, initiate a collaborative investigation of adaptive engine control with DOD and NASA laboratories, and conduct research on fluidic controllers for engines and coupled systems.
- In FY2003, we will conduct research aimed at validating advanced sensors for fuel cell single cell & stack diagnostics, begin collaborative diagnostics on full turbine engines to provide baseline information for engine simulation, research radical new engine concepts for combined heat and power (e.g., thermoacoustics, pulse detonation, thermionics), develop a research facility for evaluating novel fuel cell (within stack) flow and energy management concepts.
- In FY2004, we will conduct laboratory research to validate hypotheses involving adaptive combustion, and validate a concept for active ignition-based knock control in reciprocating engine.
- In FY2005, we will complete studies of the first hybrid fuel cell/gas turbine configuration, and field-test high-temperature sensor materials in advanced turbines.